"A SAFETY DEVICE"

THE PRESENT INVENTION relates to a safety device, and more particularly relates to a safety device for use with a vehicle seat belt.

It has been proposed to provide seat belts and also air-bags for use in a motor vehicles to restrain seat occupants during an accident situation. It is known that, for the front seats in a vehicle, if the seat belt and/or air-bag can prevent a seat occupant from reaching the dashboard or steering wheel in front of the seat during an accident, then the risk of injury to the seat occupant may be minimised.

In any accident situation the energy that has to be absorbed by the seat belt and/or air-bag to prevent a seat occupant from reaching the dashboard depends upon a number of different factors, including the severity of the accident or, in other words, the degree of deceleration experienced by the cabin of the vehicle, and also the weight of the seat occupant. It is clear that more energy has to be absorbed by a heavy person than if the seat is occupied by a light person in any particular accident situation. Also, more energy has to be absorbed in a severe high speed accident then in a gentle low speed accident.

It has been proposed to utilise a force limiter associated with a seat belt for a seat occupant, the force limiter having an adjustable force level so that the energy absorbed by the force limiter may be adjusted. For example, the force limiter may have a force level or energy absorption level that can be changed from a high level to a lower level at a controlled moment after commencement of an accident situation, or which can be changed in response to a signal indicative of the severity of a particular accident.

It is to be understood that, generally speaking, a heavy person may be capable of withstanding a much higher energy absorption level than a light person. However, it is always desirable to keep the energy absorption level applied to any seat occupant as low as possible. If a high energy absorption level is necessary, then that high energy absorption level should be used for as short a time as possible.

It has been proposed to control the energy absorption level of a force limiter by using weight sensors which determine the weight of a seat occupant, the weight sensors providing signals to a control unit, with the control unit then selectively adjusting the energy absorption level of a force limiter. The control unit may control the energy absorption level not only in dependence upon the weight of the seat occupant, but also in dependence upon the severity of the accident, thus providing a very sophisticated arrangement. However, such an arrangement is very expensive to implement.

The present invention seeks to provide an improved safety device.

According to this invention there is provided A safety device, the safety device incorporating a force limiter to permit the restricted paying out of a safety belt with the absorption of energy, the force limiter having a first

relatively high energy absorbing level and a second relatively low energy absorbing level, there being a first mechanism operable to select one said energy absorbing level in response to a crash related electric signal, there being a mechanical arrangement, responsive to a relative movement between two components of the safety device caused by an initial belt force in excess of a predetermined force, the mechanical arrangement directly inhibiting the effective selection of the one said energy absorbing level by the first mechanism.

Preferably the first mechanism is operable to select the second relatively low energy absorbing level and the said arrangement responsive to an initial belt force is operative to inhibit effective selection of the said second relatively low energy absorbing level. Because the mechanical arrangement directly inhibits the effective selection of one said energy absorbing level, without the generation and processing of any electric control signals, a very fast acting operation may be achieved, and at a relatively low cost.

Conveniently the device is in the form of a seat belt retractor.

Preferably the arrangement includes a two-part spindle within the retractor, a first part of the spindle being adapted to be locked, a second part of the spindle having the safety belt wound around it, the arrangement being such that the second part of the spindle may move relative to the first part when the initial belt force in excess of said predetermined force applied, the movement of the second part of the spindle relative to the fixed first part of the spindle actuating the arrangements which inhibits said one of said energy levels.

Conveniently the second part of the spindle is connected to the first part of the spindle by means of an energy absorbing torsion bar, the energy

absorbing torsion bar having two sections, a first section being operative to provide said first relatively high energy absorbing level and a second section being operative to provide said second relatively low energy absorbing level.

Preferably the said mechanism incorporates a locking element and an inhibiting element, the inhibiting element engaging part of the torsion bar between the first and the second section thereof, the locking element initially engaging part of the inhibiting element and the second part of the spindle to secure the said inhibiting element to the second part of the spindle, the locking element being moveable to a release position in which the locking element does not secure the inhibiting element to the second part of the spindle.

Conveniently the locking element is a radially moveable locking element, the locking element initially being retained in an engaged position by means of a blocking element located adjacent one end of the locking element, the said mechanism being configured to move said blocking element to a release position in response to said crash related electric signal.

Preferably the blocking element is in the form of a ring.

Advantageously the blocking element is moveable in response to the generation of gas by a pyrotechnic squib.

Alternatively the pyrotechnic squib is positioned to direct gas directly to the blocking member.

Conveniently there is a control element, the squib being positioned to direct gas to the control element to move the control element so that the

movement of the control element moves the blocking element to the release position.

Advantageously the pyrotechnic squib is associated with at least one gas duct formed in the first part of the spindle and at least one gas duct in the second part of the spindle, the said two gas ducts initially being co-aligned, so that a flow of gas may flow through both gas ducts to cause movement of the blocking element, the first part of the spindle being moveable relative to the second part of the spindle in response to said initial belt force in excess of a predetermined value, thus off-setting the gas flow ducts to prevent the flow of gas.

Preferably there are a plurality of said gas ducts in the first part of the spindle and a corresponding plurality of said gas flow ducts in the second part of the spindle.

Conveniently the blocking element is located adjacent a stop, the blocking element in one orientation being moveable past the stop, the blocking element, in any other orientation, not being moveable past the stop, the orientation of the blocking element being mounted to the second part of the spindle to be moveable with the second part of the spindle.

Advantageously the blocking element is in the form of a ring, the ring being provided with at least one inwardly directed finger, the finger being received within an axially extending groove formed in an outer region of the second part of the spindle.

Preferably the stop is formed on the first part of the spindle.

Conveniently two diametrically opposed stops are provided, each of a predetermined configuration, and the ring shaped blocking element is provided with two cut-outs of corresponding shape and configuration.

Preferably wires are provided to supply said electric signal, a part of at least one wire extending from the first part of the spindle to the second part of the spindle, the said part of the wire being configured to be broken on relative movement of the second part of the spindle relative to the first part.

Advantageously the inhibiting element is provided with a deformable portion which is configured to be deformed in response to relative movement of the second part of the spindle to a first part of the spindle, the deformable part being positioned to co-operate with a correspondingly configured part of the second part of the spindle, to engage the deformable part with the second part of the spindle so as to inhibit effective selection of said one of said energy levels.

Conveniently the deformable part is in the form of a deformable finger, the finger being deformed into a shaped recess provided within part of the second part of the spindle.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated, the invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIGURE 1 is a part sectional and part diagrammatic view of one embodiment of a retractor spindle forming a safety device in accordance with the invention,

FIGURE 2 is a view corresponding to Figure 1 illustrating a modified embodiment of the invention,

FIGURE 3 is a view taken on the line III-III of Figure 2, with Figure 3 showing the line II-II forming the section of Figure 2,

FIGURE 4 is a side view of a component of the retractor spindle shown in Figure 2,

FIGURE 5 is a view corresponding to Figure 1 illustrating a further embodiment of the invention,

FIGURE 6 is a view taken on the line VI-VI of Figure 5 showing the line V-V of the Section of Figure 5,

FIGURE 7 is a view corresponding to Figure 5 but taken on a slightly different section and showing the situation that exists after the seat belt has been withdrawn from the retractor,

FIGRUE 8 is a sectional view taken on the line VIII-VIII of Figure 7 showing the section line VII-VII of Figure 7,

FIGURE 9 is a sectional view taken on the line IX-IX of Figure 7,

FIGURE 10 is a sectional view of the spindle of a further embodiment of a retractor constituting an embodiment of the invention,

FIGURE 11 is a sectional view taken on the line XI-XI of the spindle of Figure 10 in a first condition,

FIGURE 12 is a view corresponding to Figure 11 showing the spindle in a second condition,

FIGURE 13 is a graphical figure provided for the purpose of exploration, and

FIGURE 14 is a corresponding graphical figure.

In the described embodiments of the invention, a safety device in the form of a seat belt retractor is provided, the retractor having a spindle formed from a spindle body and a spindle head, the spindle being mounted for rotation and having part of the seat belt wound around the spindle. The spindle head is associated with a lock which serves to lock the spindle head to part of the chassis in the event that an accident occur. A torsion bar arrangement extends between the spindle head and the spindle body so that, when the spindle head is locked, the spindle body may rotate relative to the spindle head with energy being absorbed by the torsion bar.

The torsion bar is provided with two sections, one section being very stiff and thus providing a high energy absorbance, and the other part being relatively soft and thus providing a relative energy absorbance. A locking element is provided which is releasable in response to a signal, such as an electric signal from a crash sensor, the locking element initially serving to

inhibit the effective operation of the soft section of the torsion bar. The crash sensor may respond to the acceleration of part of the vehicle forming the passenger cabin. The sensor will provide a signal at an earlier instant in a severe crash, than in a gentle or soft crash. The signal is provided when the sensed acceleration exceeds a predetermined threshold value. The locking element may be released to permit effective operation of the soft section of the torsion bar at a predetermined instant during an accident situation. However, if the force applied to the belt is sufficient to rotate the body of the spindle by a predetermined amount relative to the head of the spindle during an initial phase in an accident situation, i.e. before the crash sensor generates a signal, release of the locking element is prevented or a separate locking arrangement is actuated so that, in such a situation, only the relatively stiff part of the torsion bar will be operative.

A high force will be applied to the belt when the seat occupant is heavy, or when the crash is a severe crash. By selecting the threshold acceleration of the crash sensor appropriately the high force will be experienced by the belt before the sensor generates a signal, regardless of the severity of the crash, only for a heavy seat occupant. The average or light seat occupant, in a severe crash, will only provide a high force in the belt relatively late in the crash. Thus the stiff part of the torsion bar will only be operative for a heavy seat occupant.

Referring initially to Figure 1 of the accompanying drawings, the operative parts of the spindle a retractor are shown in cross-section. The retractor incorporates a spindle 1 onto which is wound part of a safety belt 2. The spindle 1 incorporates a spindle body 3 provided with spaced apart radially extending flanges 4,5 which are of different sizes, but which define between them a trough 6 to receive the seat belt 2. One end of the spindle body 3 defines a trunnion 7 by means which the spindle is rotatably supported, the

trunnion 7 being associated with a helical or “clock” spring 8 to bias the spindle 1. At the other end of the spindle body 3, a spindle head 9 is provided, the spindle head 9 defining a second trunnion 10 by means of which the spindle is rotatably supported. The spindle head is mounted to the spindle body 3 so as to co-rotate with the spindle body 3 during ordinary operation of the retractor.

The spindle head 9 is associated with a lock 11 which responds to an accident situation, or a potential accident situation, to lock the spindle head 9 relative to part of the chassis 12 of the vehicle to prevent rotation of the spindle head to prevent the free paying-out of the safety belt 2.

The interior of the spindle 1 defines a cavity 13. Contained within the cavity 13 is an axially extending torsion bar 14. The torsion bar 14 has a first enlarged end region 15 which is provided with peripheral keyways or protrusions, the end region 15 being received within a correspondingly configured recess 16 provided on the interior of the spindle head 9, so that the end region 15 of the torsion bar 14 is securely and non-rotatably connected to the spindle head 9. It is thus to be understood that when the spindle head 9 is locked by the lock 11 to the chassis 12, the head 15 of the torsion bar 14 cannot rotate.

Extending from the head 15 of the torsion bar is a relatively stiff first region 17 of the torsion bar, which provides a high energy absorption level. At an approximately central point of the torsion bar 14 an enlarged radius portion 18 is provided, the enlarged radius portion 18 having a peripheral keyways or projections. Extending from the central portion 18 of the torsion bar 14 is a second torsion bar region 19, this torsion bar being of lesser diameter or being of softer material than the stiff torsion bar region 17, the torsion bar region 19 thus being a “soft” region. This region will provide a

lower energy absorption level. The second region 19 of the torsion bar terminates with an enlarged end part 20, the end part 20 being provided with peripheral keyways or recesses, the end part 20 being received within a correspondingly configured recess 21 provided in the spindle body 3 adjacent the trunnion 7. It is thus to be appreciated that the end 20 of the torsion bar 14 will co-rotate with the spindle body 3.

The exterior of the central region 18 of the torsion bar 14 is engaged with a correspondingly configured end portion 22 of a tube 23 which surrounds the first or stiff portion 17 of the torsion bar 14. The tube 23 acts as an inhibiting element which can inhibit effective operation of the second region 19 of the torsion bar. The other end 24 of the tube is enlarged and has an exterior surface configured to engage a radially moveable locking element 25, the locking element 25 passing radially through a bore provided in part of the flange 5 of the spindle body 3 which surrounds the cavity 13. There may be two or more locking elements 25. The configuration of the end part 24 of the tube 23 and the radially innermost end of the locking element 25 is such that when the inner end of the locking element 25 engages the exterior of the end 24 of the tube 23 the tube 23 cannot rotate relative to the spindle body 3. However, the locking member 25 may move radially outwardly, thus becoming disengaged from the end 24 of the tube 23, then permitting the tube 23 to rotate relative to the spindle body 3. The locking element 25 may be spring biased radially outwardly, or, alternatively, the radially inner end 25 of the locking element 25 may be contained within a recess formed in the periphery of the end part 24 of the tube 23 which has at least one sloping wall such that relative rotation between the end part 24 of the tube 23 and the spool body 3 causes the locking element to be driven radially outwardly thus becoming disengaged from the end part 24 of the tube 23.

A blocking ring 26 is provided which is initially located immediately adjacent the radially outermost end of the locking element 25 where it projects through the radially outermost part of the flange 5 provided on the spool body 3. The blocking ring 26 is initially positioned so that the blocking ring prevents the locking element 25 from moving radially outwardly to the release position in which the locking element 25 is disengaged from the end part 24 of the tube 23.

Associated with the blocking ring 26 is a pyrotechnic squib 27, the squib 27 being associated with a gas directing tube 28 to direct gas from the squib to a control ring 29, the control ring 29 initially being located adjacent the blocking ring 26. It is to be appreciated that on actuation of the squib, gas will flow through the guide 28, and will move the control ring 29 so as to displace the blocking ring 26 from its initial position, then permitting the locking element 25 to move radially outwardly to the release position.

The squib 27 is controlled by a control signal from a controller 30, the signal passing through wires 31. One of the wires 31 has a loop 32 which extends through part of the spindle head 9, and through part of the spindle body 3. It is to be appreciated that if the spindle body 3 moves relative to the spindle head 9, then the loop 32 will be broken, thus inhibiting actuation of the pyrotechnic squib 27 even if a control signal is generated by the controller 30.

It is to be envisaged that in ordinary operation of the retractor illustrated in Figure 1, the spindle 1 will tend to wind in the seat belt 2 under the influence of the spring 8. Ordinarily the belt may be pulled out from the retractor and will be rewound into the retractor under the biasing effect provided by the

spring 8. Should the vehicle decelerate the lock 11 may lock, thus locking the spindle head 9 to chassis 12.

In the event that a major accident occurs, the lock 11 will lock the spindle head 9 to the chassis 12. The seat occupant will be thrown forwardly and a force will be applied to the seat belt 2. The force will tend to rotate the spindle 1, but free rotation of the spindle is prevented by the locking effect provided by the lock 11. For a heavy seat occupant a high force level will be generated in the seat belt, corresponding to the torque level of the stiff part of the torsion bar at an early instant in the crash, before the signal 1 is generated by the crash sensor. This force will tend to cause the spindle body 3 to rotate relative to the locked spindle head 9, thus causing the stiff portion of the torsion bar 14 to absorb energy and become slightly "twisted", since the engagement between the flange 5 and the end part 24 of the tube 23 effected by the locking element 25 will ensure that the tube 23 rotates simultaneously with the spindle body 3, thus ensuring that the central part 18 of increased diameter of the torsion bar 14 rotates with the spindle body 3. Thus, the relatively stiff portion 17 of the torsion bar will become twisted. As a consequence of the relative movement between the spindle body 3 and the locked spindle head 9, the loop 32 of wire will be broken. Even if, at a subsequent stage during the accident, a signal is generated by the control unit 30, the squib 27 will not be actuated. Thus only the relatively stiff part of the torsion bar will be operative.

On the other hand, if the accident is a relatively "gentle" accident, or if in a severe accident the seat occupant is of average weight or light, the force applied by a seat occupant to the belt 2 during the initial stage of the accident before the crash sensor generates a signal will be less than the torque level of the stiff part of the torsion bar. The force will not be sufficient to rotate the

spindle body 3 relative to the locked spindle head 9, and thus the loop 32 will be undamaged when the crash sensor operates the signal.

At a subsequent stage during the accident the controller 30 generates a control signal which is passed by the wires 31 to the squib 27. The squib 27 will ignite, generating gas which is directed by the guide 28 to the control ring 29. The control ring 29 moves to displace the blocking ring 26. Since the blocking ring 26 is displaced the locking element 25 may move outwardly under a spring bias, if such a spring bias is provided, or will at least be free to move outwardly. Because the locking elements 25 may move outwardly, and the tube 23 no longer acts to retain the central enlarged diameter portion 18 of the torsion bar 14 in a fixed position relative to the spindle body 3. Consequently the only effective connection between the spindle body 3 and the locked spindle head 9 is the entire length of the torsion bar, since one enlarged end 15 of the torsion bar is connected to the spindle head 9 and the other enlarged end 20 of the torsion bar 14 is connected to the spool body 3. Any rotational force applied to the spool body 3 will thus tend to twist the relatively small diameter or relatively soft section 19 of the torsion bar, which will absorb energy, but only at a relatively low level.

It is thus to be appreciated that in the described embodiment of the invention if the seat occupant is heavy, the force initially applied to the safety belt 2 will ensure that, during subsequent stages of the accident, deployment of the relatively soft or smaller diameter section 19 of the torsion bar is effectively prohibited or inhibited. However, if the seat occupant is of average weight or light, the relatively soft or small diameter section 19 of the torsion bar may become operative.

Turning now to Figure 2 of the accompanying drawing a modified embodiment of the invention is illustrated. Whereas, in the embodiment of Figure 1, rotation of the spindle body 3 relative to the fixed spindle head 9 causes a wire loop to break, in the embodiment of Figure 2, which in many respects closely resembles the embodiment of Figure 1, a gas flow passage from the pyrotechnic squib becomes closed off as a consequence of rotation of the spindle body relative to the fixed spindle head 9, thus preventing gas from the squib effecting movement of the blocking ring to a release position when the squib is actuated.

Turning to Figures 2 to 4 it is to be noted that the spool 1 is generally as described in the embodiment of Figure 1, save that the design of the flange 5 has been modified, and also the location of the pyrotechnic squib has been changed.

Elements 1 to 26 of the embodiment shown in Figure 2 correspond directly with the corresponding elements of Figure 1 and thus these elements will not be redescribed at this stage.

It is to be noted that in the embodiment of Figure 2, a pyrotechnic gas generator 40 is provided which receives signal, along wires 41, from an appropriate controller. The pyrotechnic squib is provided with a gas outlet duct 43 which leads to a plurality of gas flow passages 44 provided in the spindle head 9. The gas flow passages 44 extend to a generally cylindrically portion 45 of the spindle head 9, and emerge as a series of staggered and offset gas flow openings 46 provided in the side wall of the cylindrical portion 45.

It can be seen that the end part of the spindle body 3 which carries the flange 5 has been modified and includes a corresponding plurality of gas flow

passages 47, the gas flow passages 47 terminating in openings formed in a generally tubular terminal portion of the spindle body 3 which is slidingly mounted on the cylindrical portion 49 of the spindle head 9. The gas flow passages 47 terminate immediately adjacent the blocking ring 26, the blocking ring 26 serving to prevent axial movement of locking element 25.

It is thus to be appreciated that when the spindle body 3 is in an initial position relative to the fixed spindle head 9 the gas flow passages 44 are co-aligned with the gas flow passages 47 and, with the spindle 1 in this condition if the pyrotechnic squib 40 is actuated gas will flow through the gas guide 43 and through the co-aligned gas flow passages 44 and 47, the gas thus being applied to the blocking ring 26 and moving the blocking ring from an initial blocking position as shown in Figure 2 to a release position in which the locking element 25 may move radially outwardly.

It is to be appreciated, however, that if, during an initial stage of an accident, the spindle body 3 rotates slightly with respect to the fixed and locked spindle head 9, and any such movement would be against a resisting force provided by the relatively stiff portion 17 of the torsion bar 14, then the gas flow passages 44 will be offset from the gas flow passages 47, and on actuation of the pyrotechnic squib 40 no gas will flow through the gas flow passages 47 and thus the blocking ring 26 will remain in its initial condition.

Thus, in the operation of this embodiment of the invention, in any accident situation in which the occupant is relatively light, the level of force applied by the belt 2 to the spindle body 3, after the initial locking of the spindle head 9 will not reach a level corresponding to the stiff part 17 of the torsion bar 14 before the crash sensor generates the signal. Thus the spindle body 3 will not move relative to the locked spindle head 9 and the gas flow

passages 44 and 47 will remain in co-alignment. If a signal is then provided to the pyrotechnic squib 40, the gas from the pyrotechnic squib will move the blocking ring 26 to a release position.

However, for a heavier occupant, a large force is applied to the belt 2 very shortly after the initial locking of the spindle head 9, and before the crash sensor generates the signal. The force will exceed the torque of the stiff part 17 of the torsion bar 14, and thus the spindle body 3 will rotate relative to the fixed head 9, with energy being absorbed by the relatively stiff torsion bar 17. Consequently the gas flow passages 44 will be off-set from the gas flow passage 47. Thus on actuation of the squib no gas will flow to the blocking ring 26 and the end result will be that the blocking ring 26 will not be moved to the release position, and only the relatively stiff section17 of the torsion bar 14 will be operative.

Figures 5 to 9 illustrate another embodiment of the invention which again closely resembles the embodiments described above with reference to Figures 1 to 4. In the embodiment of Figure 5 to 9 a spool 1 is again of a very similar design to that described above, and again elements 1 to 26 of this embodiment are generally as described in the embodiment of Figure 1.

It is to be noted in the embodiment of Figures 5 to 9 the blocking ring has been slightly modified so as to co-rotate with the spindle body 3. The blocking ring is located adjacent a stop arrangement and can only move past the stop arrangement when in one predetermined relative position, that relative position being the position adopted initially. Thus, on relative rotation having occurred between the spindle body 3 and the locked spindle head 9 the blocking ring can no longer be moved to the release position.

Looking now in more detail at the embodiment of Figures 5 to 9, it can be seen that the blocking ring 26 is of generally annular form, but is provided with radially inwardly directed fingers 50 which are slideably recessed in axial grooves 51 formed in the flange 5 provided at the end of the spindle body 3 adjacent the fixed spindle head 9. The blocking ring 26 may thus move axially of the spindle body 3, whilst relative rotation between the blocking ring 26 and the spindle body 23 is prevented by the engagement of the fingers 50 with the axial grooves 51.

However, the blocking ring 26 is also provided with cut outs 53,54 formed in the inner circular wall of the annular ring 26. The cut out 53 is relatively shallow and relatively broad whilst the cut out 54 is relatively narrow but relatively deep.

The spindle head 9 is provided with radially outwardly directed stop flanges 55, 56. The stop flange 55 is relatively short and relatively broad, thus having a configuration corresponding to that of the cut out 53, whereas the stop flange 56 is relatively narrow and relatively long, thus corresponding to the form of the cut out 54.

It is to be understood that a pyrotechnic unit 57 is provided associated with a gas guide 58 which serves to direct gas towards a control ring 59 such that the control ring 59 is moved to a position in which it tends to displace the blocking ring 26 axially of the spindle body 3.

It is to be appreciated that with the spindle body 3 in a first relative position, as compared with the spool head 9, the blocking ring 26 may be moved axially away from the initial blocking position, as shown in Figures 5

and 6. Thus, as in the earlier described embodiments, if no substantial force is applied to the spindle body, the blocking ring may be moved to a release position, making the soft part 19 of the torsion bar operative. When there has been rotation of the spindle body 3 relative to the fixed head 9, with energy being absorbed by the relatively stiff section 17 of the torsion bar 14, as a consequence of a large force being applied to the spindle body 3 after locking of the spindle head 9, because the cut-outs 53 and 54 will be off-set from the blocking flanges 55 and 56 (as shown in Figure 8), and the blocking ring 26 may not move to the release position and only the stiff part 17 of the torsion bar 14 will be operative.

Thus, in this embodiment, if, during a preliminary stage in an accident, a very heavy force is applied to the seat belt 2 by a heavy seat occupant before the crash sensor generates the signal, the spindle body 3 will move relative to the locked spindle head 9, and the cut outs 53 and 54 on the blocking ring 26 will not remain aligned with the stop flanges 55, 56.

However, if only a force less than the torque of the stiff section 14 of the torsion bar is generated before the crash sensor generates a signal, for example in a minor accident or with a light seat occupant, the spindle body 3 will not be rotated relative to the fixed spindle head 9 and the pyrotechnic squib will then be actuated to move the blocking ring 26 to a release position enabling the relatively soft section 19 of the torsion bar 14 to become effective.

Turning now to Figures 10 to 12 a further modified embodiment of the invention is illustrated. As in the previously described embodiments, in this embodiment the elements 1 to 26 are generally as described in Figure 1.

In this embodiment of the invention there are two mechanisms for locking a tube which engages the enlarged diameter central portion 18 of the torsion bar 14, one being releasable, in the manner as described above by moving a blocking ring 26 to enable a locking element 25 to move to a release position, and the other being actuable in response to a predetermined movement of the spindle body relative to the locked spindle head.

Turning initially to Figure 10, a tube 60 surrounds the whole length of the torsion bar 14. A central portion of the tube 60 is configured to engage with the periphery of the enlarged diameter central portion 18 of the torsion bar 14.

One end 61 of the tube 60, being the end closer to the spring 8, is associated with radially moveable locking members 25 which are associated with a blocking ring 26. Provided adjacent the blocking ring 26 is a pyrotechnic squib 62 which is configured to receive a signal on wires 63. The squib 62 is associated with a gas guide 64 which serves to guide gas from the squib to a control ring 65, so that the control ring 65 may move to displace the blocking ring 26 from an initial blocking position, thus releasing the locking element 25.

The other end 66 of the tube 60 surrounds an axially directed annular flange 67 which is formed on the interior of the spindle head 9. The flange 67 surrounds the recess 16 which receives the end 15 of the torsion bar 14.

The radially outermost exterior of the flange 67 is provided with two diametrically opposed part-cylindrical recesses 68, 69. The part-cylindrical recesses extend axially of the flange.

The end 66 of the tube is provided with pairs of part-circumferential parallel slits which serve to define two diametrically opposed deformable fingers 70a, 70b, the fingers each circumscribing just under 180° of the outer circumference of the annular flange 67. Each finger is provided with an inwardly depressed region 71, 72, each inwardly depressed region initially being received within a respective one of the part-cylindrical recesses 68, 69, as shown in Figure 11. As will become clear from the following description the fingers 70a, 70b are plastically formable. The flange 5 in this embodiment of the invention can be considered to be of tubular form, surrounding the combination of the flange 67 and the end 66 of the tube 60. The interior of the tubular flange 5 is provided with recesses 73, 74 which overlie the fingers 70a, 70b, each recess being of increasing radial depth. An abutment wall 75, 76 which lies in a plane which extends radially is located at the end of each recess.

It is to be understood that, on operation of the embodiment illustrated in Figures 10-12, should the seat occupant be heavy causing a substantial force be applied to the spindle body 3 after the spindle head 9 has been locked, the rotational force will be applied to the locking element 25 which engages the end 61 of the tube 60, and the tube 60 will also tend to rotate. Because the tube 60 is connected to the central enlarged diameter portion 18 of the torsion bar 14, the soft part 19 of the torsion bar is effectively inhibited from operating, and the force will be applied to the relatively stiff section 17 of the torsion bar. If the force is sufficiently large, the stiff portion of the torsion bar will tend to twist, absorbing energy.

As the stiff portion of the torsion bar twists, the entire tube 60 will rotate, including the end portion 66 which is effectively trapped between the axially extending flange 67 provided on the spindle head 9 and the generally tubular flange 5 provided on the spindle body 3. As the end 66 of the tube

rotates, so the inwardly depressed regions 71, 72 formed in the fingers 70a, 70b will ride up out of the part-cylindrical recesses 68, 69, thus plastically deforming the fingers 70a, 70b moving the fingers outwardly into the respective recesses 73, 74.

If, at a later instant in an accident situation, the squib 62 is actuated to move the control ring 65 so that the blocking ring 26 is moved to a release position, thus enabling the locking element 25 to move outwardly, to release the spindle body from the end 61 of the tube 60, any attempt to pay-out further safety belt will rotate the spindle body 3 and will cause the abutment walls 75, 76 to be brought into engagement with the adjacent ends of the deformed fingers 70a, 70b which have been moved into the recesses 73, 74. Thus, as the spindle body 3 rotates to pay out safety belt 2, the tube 60 will co-rotate with the spindle body 3,and because the tube 60 is connected to the enlarged diameter section 18 of the torsion bar 14, the relatively stiff portion of the torsion bar 17 will be effective and will absorb energy.

On the other hand, if no substantial force is applied to the spindle body 3 after the initial locking of the spindle head 9, the fingers 70a, 70b will not be deformed, and the cylindrical part 5 of the spindle may rotate freely around the end 66 of the tube 60. In such a situation, when the blocking ring 26 is moved to the release position, there is no effective connection between the spindle body 3 and the tube 60 and then the only effective connection between the spindle body 3 and the locked spindle head 9 is the torsion bar 14. Thus, any force applied to the spindle body 3 will tend to cause the soft part 19 of the torsion bar to deform, with a relatively low energy absorbance.

It is to be appreciated that in the described embodiments of the invention, when the spindle head is initially locked and a force is applied to the

spindle body, if the force is below a predetermined threshold, there is no effective change, and when an appropriate electric signal is generated and the locking element is moved to the release position the soft part of the torsion bar becomes effective whereas, if a force in excess of a predetermined threshold is initially applied to the spindle body, there is a relative movement between the spindle body and the spindle head, this relative movement actuating a mechanical inhibitor arrangement which acts to inhibit operation of the soft section of the torsion bar.

Figure 13 is a graphic figure illustrating force and acceleration plotted against time.

The force F is marked with two levels, F1 and F2, F1 being the relatively high force associated with the stiff section 17 of the torsion bar and F2 being a lower force associated with the soft section 19 of the torsion bar.

Acceleration extends downwardly, and a threshold acceleration a1 is shown. This is the threshold acceleration sensed by the sensor which generates the signal.

In an initial accident which is illustrated in Figure 13 by the line 80, the acceleration experienced by the sensor is shown, the acceleration being substantial, because of the severity of the accident, and thus passing the threshold a1 and a time t1.

During the period between the commencement of the accident and the time t1 a heavy seat occupant, represented by line 81, will have been thrown forwardly against the seat belt in such a way that very rapidly the force applied to the seat belt 81 rises to the level of the force of the stiff part 17 of the torsion

bar. The force experienced by the belt reaches the level F1 associated with the stiff part of the torsion bar before the instant t1. Consequently the stiff part of the torsion bar then becomes operative, and operation of the soft part of the torsion bar is prevented. Consequently the line 81 continues at the level F1, showing that energy is absorbed by the torsion bar at that level during the subsequent moments of the accident.

However, if the seat occupant in the heavy accident is a light seat occupant, as indicated by the line 82, the force exerted by the seat occupant on the seat belt will, between the commencement of the accident and the time t1, only slightly exceed the force F2. Because, at the instant T1, the force has not exceed F1, operation of the "soft" part of the torsion bar 19 is not inhibited and thus, at instant t1 the soft part of the torsion bar becomes operatives, and energy is absorbed at the force level F2.

Figure 13 also illustrates a soft or gentle accident. In such an accident the acceleration experienced by the sensor is much less than the acceleration experienced for the severe accident, as shown by line 83. Line 83 only reaches the threshold at an instant t2, which is a long time after the instant t1.

Nevertheless, the force applied to the safety belt during this accident by a heavy seat occupant, as shown by line 84, still rises to reach the value F1, the value associated with the stiff part of the torsion bar, before the instant t2 is reached. Also, as shown by the line 85, in this accident the force applied to the safety belt by a light occupant, even at instant t2 has not exceeded the level F1. The force, as illustrated, has exceeded the level F2, but as soon as the instant t2 is reached, the soft part of the torsion bar becomes operative enabling energy to be absorbed at the energy level F2.

Figure 14 is a view corresponding to Figure 13, but illustrates the situation that exists in an embodiment of the invention in which there is some play between the torsion bar and the tube. In this embodiment of the invention the force applied to the retractor by the seat belt when a heavy occupant is involved in a severe accident rises swiftly to the level F2. Because there is some play in the system, at this instant, the soft part of the torsion bar will be twisted slightly as the play is taken up. Thus some energy is absorbed with the force F2. This movement prevents the selection of the low energy level, and the force exerted by the belt continues to rise, past the instant t1, until the force level F1 is reached, when the stiff part of the torsion bar absorbs the energy.

In contrast, for a light seat occupant involved in a severe accident, as shown by line 82, the force exerted by the belt has not reached the level F2 by the instant t1. Thus, the force exerted by the line 82 continues to rise until the level F2 is reached when the energy is then absorbed by the torsion bar. It is to be observed that by using this expedient, the light occupant is never subjected to a force in excess of F2.

Lines 84 and 85 show that a similar situation exists with a severe accident.

Here again the heavy occupant causes the soft part of the torsion bar to twist, due to the "play" in the system, before instant t2, thus inhibiting effective selection of the soft part of the torsion bar. Also the light seat occupant does not exert a force equivalent to the force level F2 until after the instant t2, and thus again is never subjected to a force greater than the force F2.

It is to be appreciated that in all of the described embodiments, any initial movement of the spindle body 3 is effected against an energy absorbing effect provided by the relatively stiff portion 17 of the torsion bar 14. In alternative embodiments of the invention, if initially there is some “slack” or “play” between the enlarged diameter central section 18 of the torsion bar 14 and the tube 23, or between the tube and the locking elements an initial movement of the spindle body 3 may be effected relative to the fixed head 9 with energy being absorbed by the relatively soft portion 19 of the torsion bar 17. This may be preferred in certain embodiments of the invention, where only a relatively low initial force indicates that operation of the soft part of the torsion bar should be inhibited.

Whilst the invention has been described with reference to a spindle for a belt retractor, the invention may be embodied in an energy absorbed associated with a seat belt buckle, or a seat belt pretensioner.

In the present Specification "comprises" means "includes or consists of" and "comprising" means "including or consisting of".